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(54) Method for automatically controlling a vehicle.

(57) This invention relates to a method of automatic vehicle operation which fulfills multi-dimensional performance indices by presetting the weight for power consumption, the weight for the riding confort, and the like. The modifying running time relative to the standard running time to be spent between two stations, the allowable power consumption relative to the standard power consumption to be spent for the standard running between two stations, and the degree of improvement of riding confort for the standard running between two stations are set prior to the departure from a station so as to determine control parameters to be used for divided regions of distance between two stations, and the speed of the vehicle between two stations is controlled using the selected control parameters.

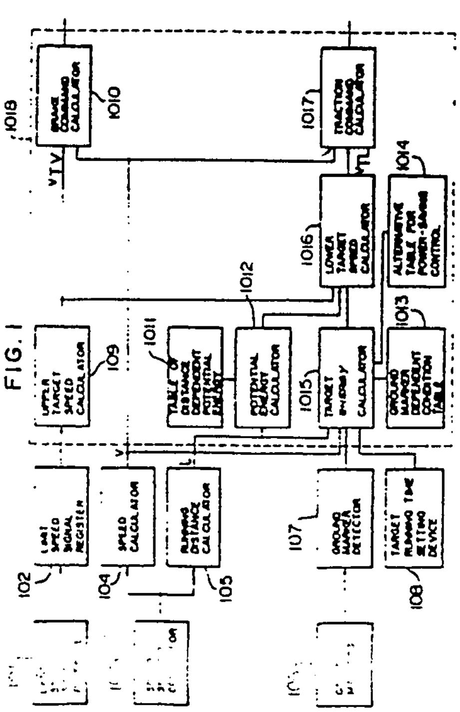


FIG. 1

0 257 662 A2

METHOD FOR AUTOMATICALLY CONTROLLING A VEHICLE

The present invention relates to a method for automatically controlling a vehicle.

Recently, methods of automatic operation of a train have been put into practice in various places in the world. In these conventional methods, a target speed pattern is generated, and control commands are issued to the traction controller or brake controller so that the actual train speed follows the target speed pattern (For example, refer to Japanese Patent Laid-open No. 57-36505.) For operating a train between two stations, according to these methods, a number of running patterns are prepared in advance and the train is operated by selecting and switching the running patterns depending on situations such as a delay on the train diagram. These methods are solely oriented to bring a train conformable to the diagram through the selection of a running pattern based on the running time. More recently, however, there arise demands for lower power consumption and better riding comfort in addition to the accurate operation on the train diagram. Examples of new demands are 10% power reduction in the summer season when the gross power consumption hits the peak and better riding comfort without vibration when there are few passengers, and the operation based on such multi-dimensional performance indices is not possible by the conventional method for the automatic train operation.

It is an object of the present invention to provide a method for automatically controlling a vehicle in such a manner that multi-dimensional performance indices including weights for the power consumption, riding comfort, and so on, can be fulfilled. The invention meets with this object by the method called for in claim 1.

The present invention will become more apparent from the following detailed description of an embodiment, taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram of an automatic train operation controller;

Fig. 2 is a graph used to explain the kinetic energy possessed by a train running between two stations;

Fig. 3 is a graph used to explain the train speed in the same operating condition as in Fig. 2;

Fig. 4 is a table showing the contents of the condition table provided in correspondence to the ground markers shown in Fig. 1;

Fig. 5 is a table showing the contents of the alternative table shown in Fig. 1 for power-saving control;

Fig. 6 is a flowchart showing the process carried out at train departure by a microcomputer;

Figs. 7A and 7B are flowcharts showing the process of train control; and

Fig. 8 is a flowchart of the process of selecting a column of alternative table for the power saving control.

The method of automatic train operation control between two stations described below uses predetermined control parameters, wherein one or more ground markers are placed between two stations, and there are provided a table containing the train speed, residual running time and scheduled power consumption (per unit weight) estimated when the train has passed each ground marker in a minimum possible time, and further a table containing the increased running time and decreased power consumption in case the lower target speed is lowered for a certain distance after the train has passed each ground marker, so that the lower target speed which meets the target running time to the next station, that has been set before departure, at the least power consumption is determined when the train passes each ground marker.

The embodiment will now be described in detail. Fig. 1 is a block diagram showing the second embodiment of the automatic train operation controller. In the figure, reference number 101 denotes a device for receiving the limit speed signal at the current position of the train, 102 is a register for holding the limit speed signal, and 103 is a speed sensing generator. Reference number 104 is a speed calculator which counts distance pulses produced by the speed sensing generator 103 to calculate the train speed v from the running distance in a past second. Reference number 105 is a running distance calculator which counts distance pulses since the train has departed so as to evaluate the running distance ℓ from the departing station. Reference number 106 is a ground marker placed at a certain position between two stations, and a signal is generated in a ground marker detector 107 when the train passes the marker. The running distance measured at the detection of the ground marker 106 may be used to correct the error of the speed sensing generator.

Reference number 108 is a device for setting the target running time spent until the train will stop at the arriving station, and the device is set when the train starts from the departing station.

The target running time and target power consumption are set either through the switches equipped on the train or from the computer in the central operation command office through the communication line. The scheduled arriving time and power consumption are displayed in the train.

Reference number 1018 denotes a microcomputer which realizes the control functions by executing the stored programs as will be described shortly. In Fig. 1, the program is divided into functional blocks. The microcomputer 1018 has a program 109 for calculating the upper target speed v_{TV} to be followed by the train based on the contents of the limit speed signal register 102 and a program 1010 which calculates the brake command based on the upper target speed v_{TV} and train speed v. Reference number 1011 is a table containing the values of potential energy possessed by the train located at positions at altitudes corresponding to the distance ℓ from the departing station, and 1012 is a program for calculating the current potential energy (altitude) of the train from the distance ℓ. Reference number 1013 is a condition table corresponding to the ground markers placed between two stations, 1014 is an alternative table for power-saving control containing the values of increased running time and saved power consumption achieved when the target energy or target speed is varied at each ground marker for a certain distance, 1015 is a program for calculating the target value of energy possessed by the train, 1016 is a program for calculating the lower target speed v_{TL} by subtracting the current potential energy from the target energy, and 1017 is a program for calculating the traction command from the lower target speed v_{TL} and train speed v.

The automatic train operation controller of Fig. 1 controls the train speed using the target arrival time and power consumption calculated when the train has passed a certain position, based on the rule that the train is operated always in the same running pattern by the automatic operation for the maximum running performance thereby to achieve the minimal running time and power consumption, and in the case of alteration of control at a certain position between two stations, the original minimal running pattern can be restored with a certain increase in running time and decrease in power consumption.

Fig. 2 is a graph used to explain energy possessed by the train running between two stations, plotting the sum of potential and kinetic energies of the train on the ordinate against the distance from the departing station on the abscissa. On the graph, curve 1021 shows the kinetic energy at the limit speed, curve 1022 shows the kinetic energy at the upper target speed, curve 1023 shows the standard running energy pattern, curve 1024 shows the power-saving running energy pattern, and curve 1025 shows the potential energy of the train.

When the train is operated to run in a minimal time by simply following the upper target speed v_{TV}, the standard running energy pattern 1023 shown in Fig. 2 will be followed. Here, the power-saving running energy pattern 1024 is shown, in which ground markers are placed at three positions ℓ_{C1}, ℓ_{C2} and ℓ_{C3}, and the train is operated to run following the lower target energy setup distance and its energy value at each position, (ℓ_{E1}, E_{P1}), (ℓ_{E2}, E_{P2}) and (ℓ_{E3}, E_{P3}). This pattern is achieved by coasting. Declination of the curve is caused by the energy loss due to the running resistance such as the air resistance of the train.

Fig. 3 is a graph showing the train speed on the ordinate plotted against the distance on the abscissa in the same operation as of Fig. 2. On the graph, 1031 indicates the limit speed, 1032 indicates the upper target speed, 1033 indicates the standard running speed pattern, and 1034 indicates the power-saving running pattern. The train speeds at ground marker positions ℓ_{C1}, ℓ_{C2} and ℓ_{C3} are v_{C1}, v_{C2} and v_{C3}, respectively. These values of speed in Fig 3 are proportional to values of energy shown in Fig. 2 subtracted by the potential energy at the respective positions.

Fig. 4 shows the contents of the table 1013 provided in correspondence to the ground markers shown in Fig. 1. The column for ground marker 0 contains the initial value of standard residual running time T_{co} which is the minimum running time required at starting, and the initial value of standard power consumption E_{co} which is the power consumption per unit weight at starting. Other column for ground marker i (i ≤ 3) contains the distance ℓ_{ci} from the departing station, the threshold speed v_{ci} for the standard run, the standard (minimum) running time T_{ci} for the remaining distance, and energy E_{ci} used for the remaining distance.

Fig. 5 shows the contents of the alternative table 1014 for power-saving control shown in Fig. 1, and the table contains a plurality of records, the number of which is represented by the power-saving control factor J (J = 3). This table indicates that the running time will increase by ΔT_j and power will be saved by the amount of ΔE_j if the train runs following the lower target energy E_{pj} for a distance of ℓ_{Ej} after the train has passed the ground marker N_{Ej}, and also indicates that if this control is carried out, the control table of N_{Tj} is included in the control and cannot be used. These values can be obtained by way of simulation or through the experiment using the actual train.

Figs. 6 to 8 are flowcharts of the microcomputer embodying the present invention. The flowchart of Fig. 6 represents the operation of the processing program which is executed when the train starts. The program, initiated in response to the start command to the train, reads the running time between stations set on the target running time setting device 108 so as to set up the target arrival time (step 1031), sets the [illegible] running time to the field of initial standard running time

(T_{co}) in the condition table 1013 (step 1602), sets the power consumption to the field of initial standard power consumption (E_{co}) (step 1603), and set the power-saving control flag to "0" (step 1604).

The flowchart of Figs. 7A and 7B shows the processing of the train control program which is executed at a sampling interval of Δt (e.g., 100 ms). The program, when initiated, first subtracts the sampling time Δt from the target running time and scheduled running time (step 701). Subsequently, the program checks whether the power-saving control flag indicating the selection of the alternative table 1014 has a value j other than "0" (step 702), and resets the control flag (step 704) if the power-saving control flag is "1" (step 702) and if the running distance ℓ is larger than the control completion distance ℓ_{Ej} (step 703). If the power-saving control flag is "0" (step 705) or the running distance ℓ is in the vicinity of control completion distance ℓ_{Ej} of column j of power-saving control table under control e.g., 5 m to the end, (step 706), the program selects the power-saving control table (step 707). At this time, if the power-saving control flag is "0" (step 708), the lower target speed v_{TL} is set larger (e.g., 200 km/h) (step 709), or if the control flag has a value j (step 708), the lower target speed v_{TL} is obtained from the lower target energy E_{pj} per unit weight (having the unit of m^2/s^2) and the potential energy E_h at the current position ℓ obtained from the running distance ℓ with reference to the distance vs. potential energy table 1011 (step 710).

The potential energy E_h and lower target speed v_{TL} are calculated from the following equations.

$$E_h = G \circ h \qquad (1)$$

$$v_{TL} = 3.6 \cdot \sqrt{E_{pj} \cdot E_h} \qquad (2)$$

where G is the gravitational acceleration (9.81 m/s^2), h is the altitude (m) of the current position ℓ, and constant 3.6 is a factor for converting the unit from m/s to km/h.

Subsequently, in Fig. 7B, the program calculates the upper target speed v_{TV} from a speed corresponding to the contents of the limit speed signal register 102 (step 711). Next, the lower target speed v_{TL} obtained previously is made lower than the upper target speed v_{TV} (step 712). Then, the program calculates the brake command BN from the upper target speed v_{TV} and the train speed v provided by the speed calculator 4, using, for example, the following equation (step 713).

$$BN = (v - v_{TV}) \circ B_g \qquad (3)$$

where B_g is the gain of the brake command applied to the deviation of speed.

Subsequently, if the brake command BN is produced (step 714), the traction command PN is made "0" (step 715), or if the former is absent, the traction command is calculated using, for example, the following equation (step 716).

$$PN = (v_{TL} - v) \circ P_g \qquad (4)$$

where P_g is the gain of traction command applied to the deviation of speed. The calculated brake command BN or traction command PN is fed to the drive/brake unit (step 717), and one cycle of processing is completed.

Fig. 8 shows the flowchart of the process for selecting the alternative table of power-saving control, and this is an expansion of the step 707 shown in Fig. 7A.

When the program enters this routine, it first checks the ground marker detector 107 to see whether the train has passed a ground marker during a period between the previous and present execution of the routine. If it is found that the train has passed a ground marker i, the program checks whether or not the train speed v is faster than the threshold speed v_{ci} which is the speed to achieve the minimum running time plus a marginal speed (e.g., 2 km/h) (step 801), and if this is true, the program proceeds to step 802. In case the train has passed the ground marker i at a speed faster than the threshold speed v_{ci}, the standard residual running time T_{ci} and standard power consumption E_{ci} are set to the scheduled running time and power consumption (step 802).

Next, the whole alternative table for power-saving control 1014 is made effective (step 803). Subsequently, steps 805, 810 and 811 are carried out by incrementing the value of j by the amount of power-saving control factor J. Namely, checking is made first whether the ground marker N_{Ej} for the beginning of control in the jth record of table is equal to or larger than the current ground marker i, and also whether it is invalidated by the selection of other control record (step 805). If the jth record can be selected, the target running time is compared with the scheduled running time added by the increased running time ΔT_j, and if the train can run in time shorter than the target running time even under this control (step 806), this column j control table is selected and the scheduled running time is increased by the increased running time ΔT_j and scheduled power consumption is decreased by ΔE_j (step 807). Next, the control table N_{Tj} which has no effect during this control is invalidated (step 808). If the ground marker number for the beginning of control in the table is equal to the ground marker number i which is currently passed by the train, the power-saving control flag is made to have value j (step 809). If the power-saving

control factor J is smaller than j, the program returns to step 805, while incrementing j by one, and checks whether the table can be selected (steps 810 and 811).

According to the present invention, the train is operated while calculating the presumed arrival time at the next station and power consumption time to time, allowing the marginal time to be used for the power-saving operation, and moreover, the train operation under the specified power consumption is also made possible.

Although in the foregoing embodiment, the lower target power consumption E_{pj} is set each position of ground marker, the calculation related to potential energy may be omitted if the railroad has small variation of slope.

The alternative table for power-saving 1014 of J in number has the priority in the ascending order of the number, allowing the marginal time to be spent later and the like. The control table may be selected not only based on the running time, but on the target power consumption, or alternatively, it may be selected solely based on the target power consumption.

Although in the foregoing embodiment, the location of the train is determined using ground markers, it may be determined solely based on the running distance ℓ from the departing station. The output of the distance calculator may be corrected using the running distance ℓ obtained from the count at the detection of the ground marker and the actual distance ℓ_{cl} in the table.

As described above, this embodiment has the information table on the increased running time and saved power consumption when train is operated to follow the lower target speed or lower target power consumption after the train has passed one or more positions between two stations, allowing the selection of optimal control at each position based on the target running time, target power consumption, and the like, whereby the train can be operated to meet conditions of arrival time at the next station and power consumption.

Claims

1. A method for automatically controlling a vehicle in accordance with control commands for operating a traction controller and a brake controller of the vehicle in order to run with required speed patterns through a plurality of regions into which the distance between two stations is divided, comprising:

(a) a step of preparing

a first table (1013) containing standard train [illegible] residual running time to the next station and scheduled power consumption estimated when the vehicle is run with a standard speed pattern,

a second table (1014) containing increased running time and decreased power consumption in case the vehicle is run for a predetermined distance under a state in which its lower target speed is lowered as to each of the regions;

(b) a step of designating a target running power which is required for the vehicle running to the next station before the vehicle departs;

(c) a step of running the vehicle by said control commands in accordance with said standard speed patterns;

(d) a step of substracting the time lapsed after the vehicle departure from said target running time to calculate a target residual running time permitting the vehicle to arrive at the next station;

(e) a step of calculating a reduced target speed lower limit value for saving the power consumption corresponding to the surplus time equal to the difference between the target residual running time and the standard residual running time with reference to said first and second tables when the vehicle passes by the standard points relating to the respective regions; and

(f) a step of running the vehicle at a speed of said reduced target speed lower limit value for a predetermined distance designated by said second table.

2. A method according to claim 1, wherein said second table memorizes the lower target energy corresponding to said reduced target speed, further comprising a step of preparing a third table representative of the relation between the running distance from the departure station and the potential energy of the vehicle, and a step of calculating said reduced target speed lower limit value on the basis of said lower target energy stored in said second table and said potential energy stored in said third table corresponding to the present position of the vehicle.

3. A method according to claim 1 or 2, wherein said second table memorizes a relation among running distance under reduced speed from each of the standard points, increased running time and saved power consumption, so that the running distance under reduced speed from a standard point can include the running distance under reduced speed from the next standard point.

4. A method according to any of claims 1 to 3, wherein said standard points relating to the respective regions are determined on the basis of the departure station.

5. A method according to any of claims 1 to 3, wherein said standard points relating to the respective regions are detected by receiving signals from [illegible]

6. A method according to claim 5, wherein said ground markers placed between stations are substituted by positional information derived from the running distance measured since the trains has started from the departing station.

FIG. 1

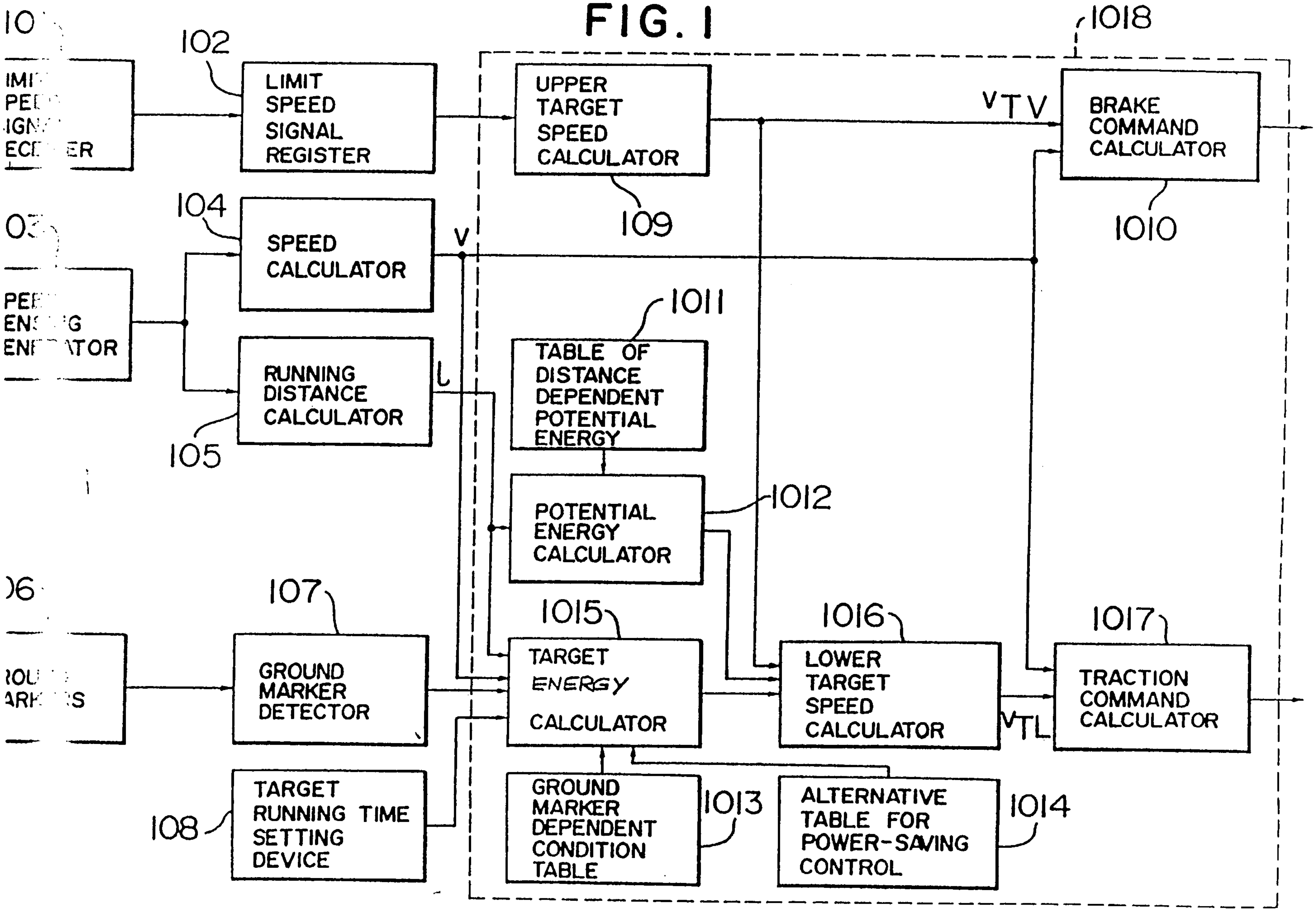

1018
LIMIT SPEED SIGNAL REGISTER
102
UPPER TARGET SPEED CALCULATOR
109
VTV
BRAKE COMMAND CALCULATOR
1010
SPEED CALCULATOR
104
V
RUNNING DISTANCE CALCULATOR
105
L
TABLE OF DISTANCE DEPENDENT POTENTIAL ENERGY
1011
POTENTIAL ENERGY CALCULATOR
1012
GROUND MARKER DETECTOR
107
TARGET RUNNING TIME SETTING DEVICE
108
TARGET ENERGY CALCULATOR
1015
LOWER TARGET SPEED CALCULATOR
1016
VTL
TRACTION COMMAND CALCULATOR
1017
GROUND MARKER DEPENDENT CONDITION TABLE
1013
ALTERNATIVE TABLE FOR POWER-SAVING CONTROL
1014

FIG. 2

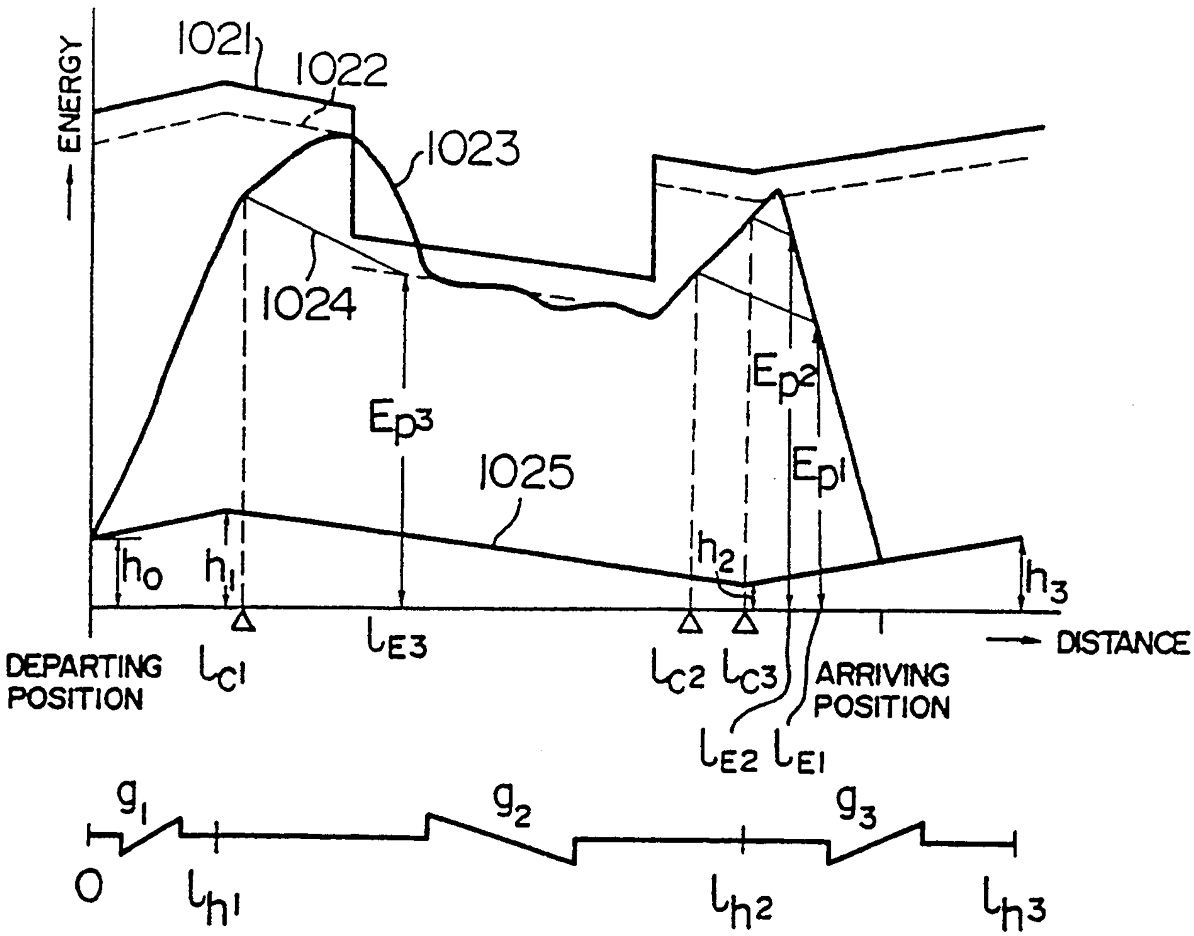

ENERGY
1021
1022
1023
1024
1025
E_{p3}
E_{p2}
E_{p1}
h_0
h_1
h_2
h_3
DISTANCE
DEPARTING POSITION
l_{C1}
l_{E3}
l_{C2}
l_{C3}
ARRIVING POSITION
l_{E2}
l_{E1}
g_1
g_2
g_3
O
l_{h1}
l_{h2}
l_{h3}

FIG. 3

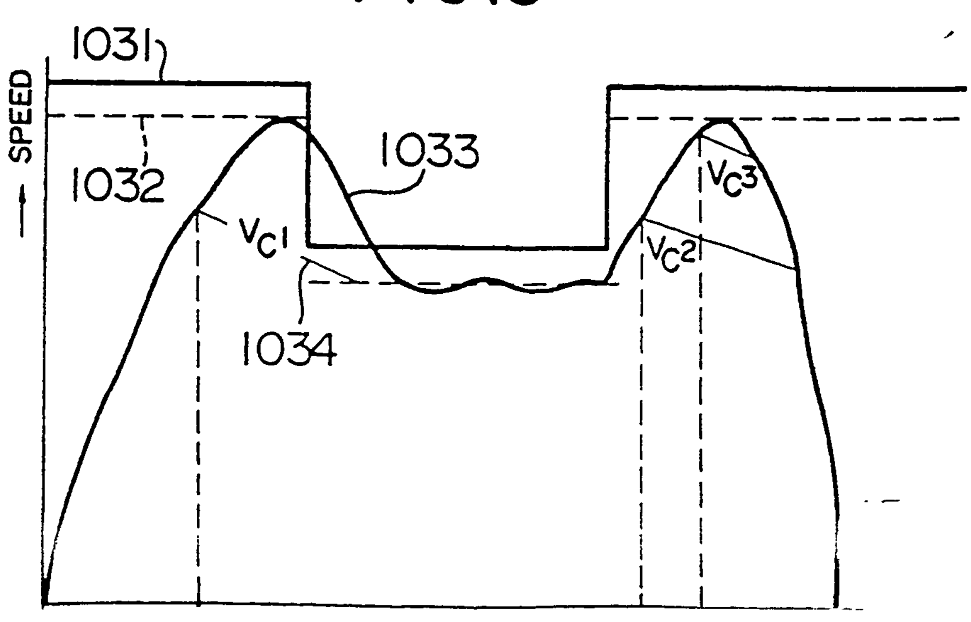

SPEED
1031
1032
1033
1034
V_{C1}
V_{C2}
V_{C3}

FIG. 4

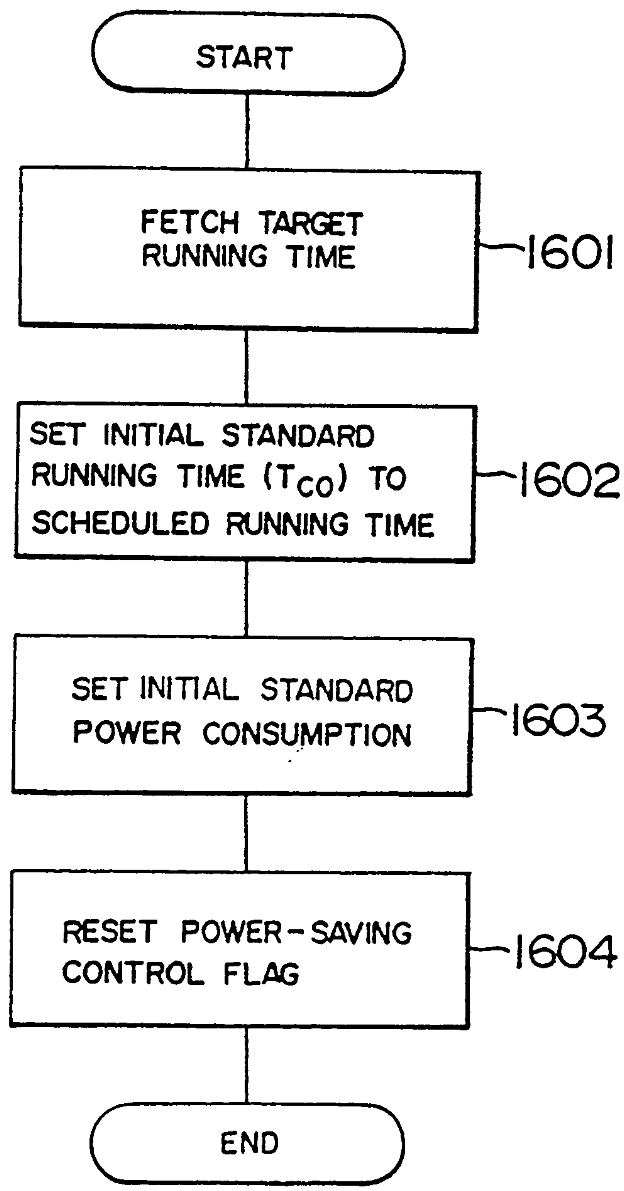
GROUND MARKER NUMBER	GROUND MARKER POSITION	THRESHOLD SPEED	RESIDUAL RUNNING TIME STANDARD	STANDARD POWER CONSUMPTION
0	0	0	T_{c0}	E_{c0}
1	l_{c1}	v_{c1}	T_{c1}	E_{c1}
2	l_{c2}	v_{c2}	T_{c2}	E_{c2}
3	l_{c3}	v_{c3}	T_{c3}	E_{c3}

FIG. 5

ER-[illegible]VING [illegible]RC[illegible] [illegible]BER	INCREASED RUNNING TIME	GROUND MARKER NUMBER	LOWER TARGET ENERGY	COMPLETE DISTANCE	SAVED POWER CONSUMPTION	TABLE NUMBER
[illegible]	ΔT_1	N_{E1} (=2)	E_{p1}	l_{E1}	ΔE_1	N_{T1} (=2)
[illegible]	ΔT_2	N_{E2} (=3)	E_{p2}	l_{E2}	ΔE_2	N_{T2} (=0)
[illegible]	ΔT_3	N_{E3} (=1)	E_{p3}	l_{E3}	ΔE_3	N_{T3} (=0)

P[illegible]WER-SAVING C[illegible]TROL FACTOR
J (=3)

FIG. 6


START
FETCH TARGET RUNNING TIME
1601
SET INITIAL STANDARD RUNNING TIME (T_{CO}) TO SCHEDULED RUNNING TIME
1602
SET INITIAL STANDARD POWER CONSUMPTION
1603
RESET POWER-SAVING CONTROL FLAG
1604
END

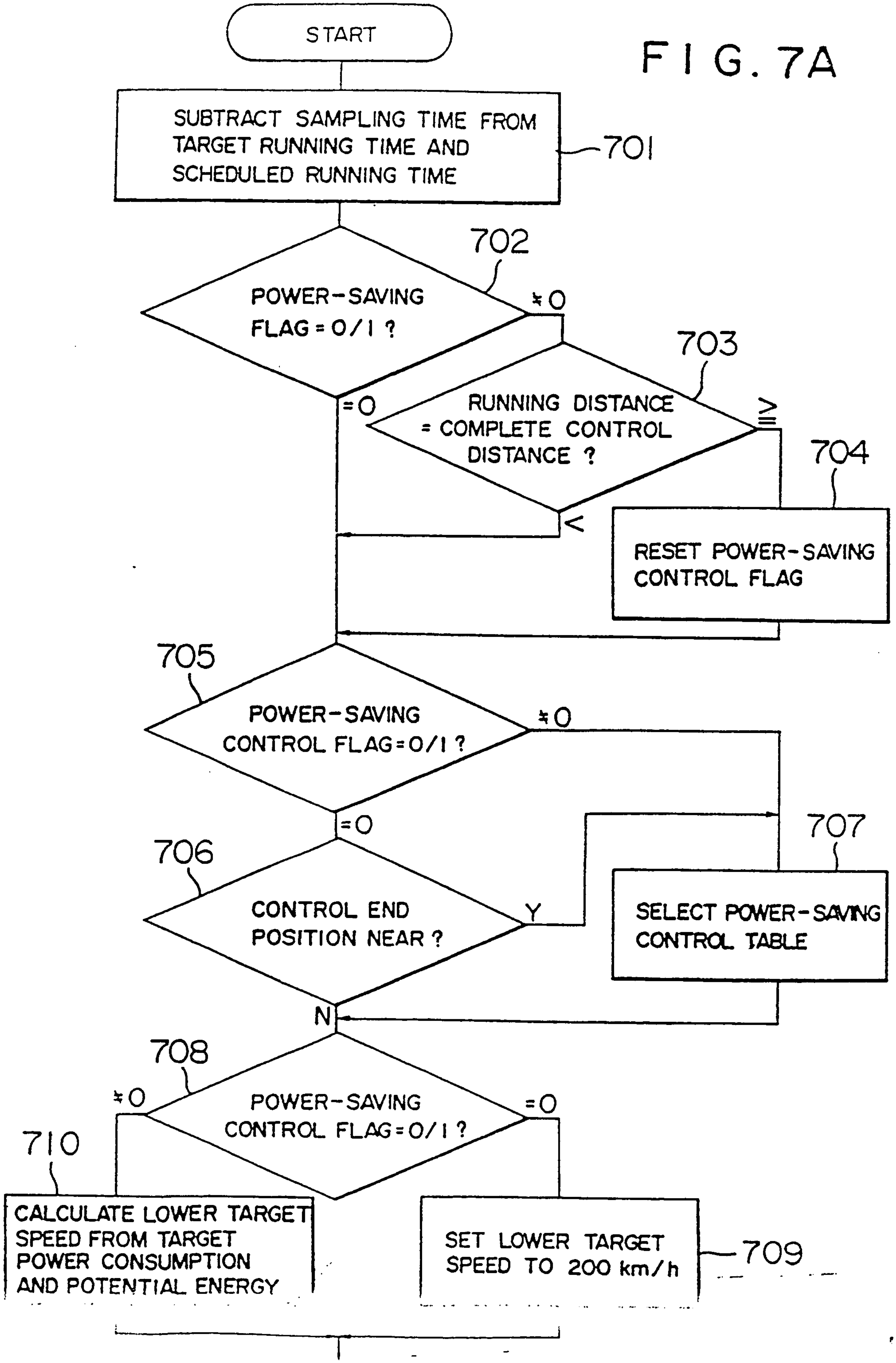

START
SUBTRACT SAMPLING TIME FROM TARGET RUNNING TIME AND SCHEDULED RUNNING TIME
701
702
POWER-SAVING FLAG = 0/1 ?
≠0
=0
703
RUNNING DISTANCE = COMPLETE CONTROL DISTANCE ?
≥
<
704
RESET POWER-SAVING CONTROL FLAG
705
POWER-SAVING CONTROL FLAG = 0/1 ?
≠0
=0
706
CONTROL END POSITION NEAR ?
Y
N
707
SELECT POWER-SAVING CONTROL TABLE
708
POWER-SAVING CONTROL FLAG = 0/1 ?
≠0
=0
710
CALCULATE LOWER TARGET SPEED FROM TARGET POWER CONSUMPTION AND POTENTIAL ENERGY
SET LOWER TARGET SPEED TO 200 km/h
709

FIG. 7A

FIG. 7B

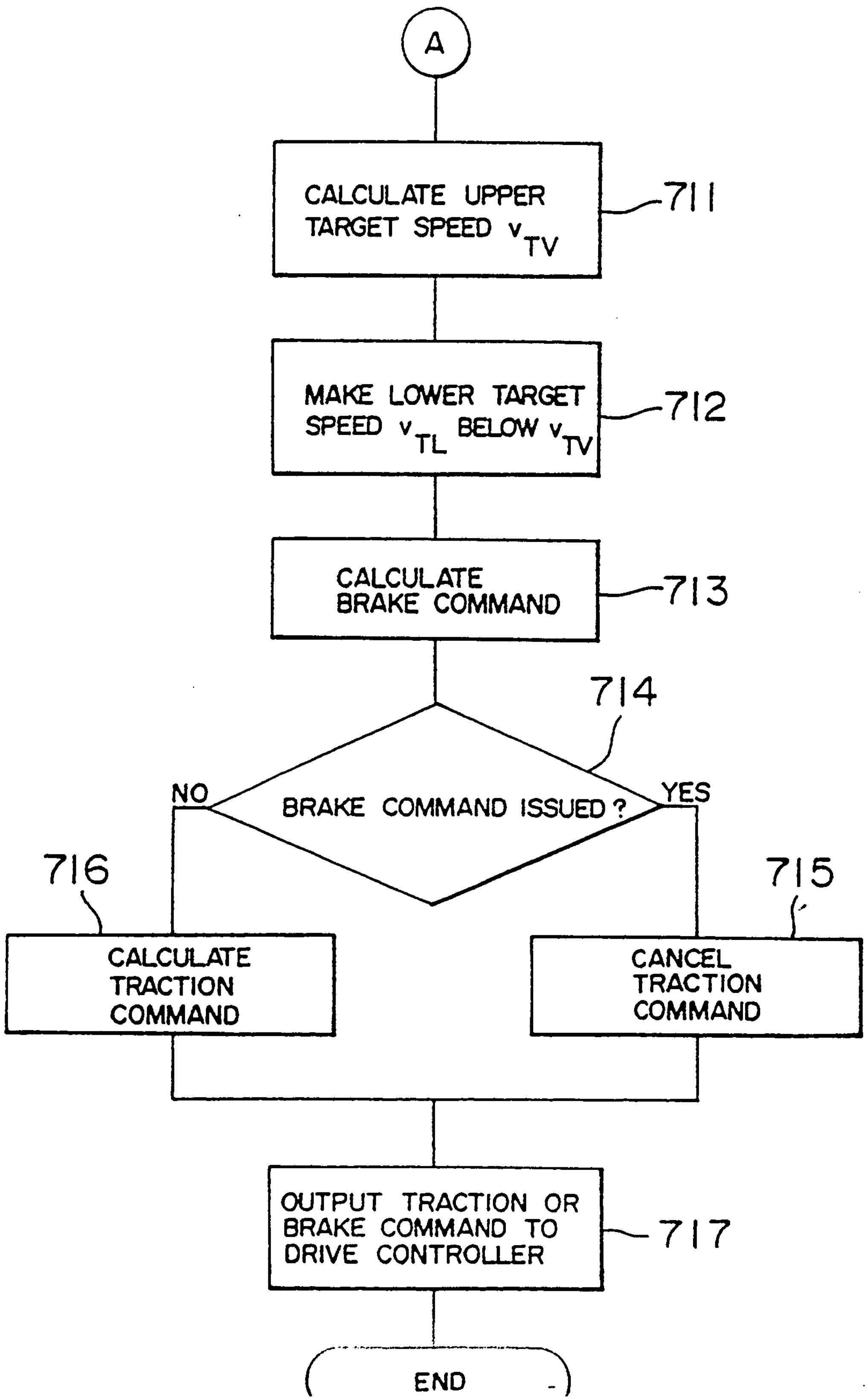
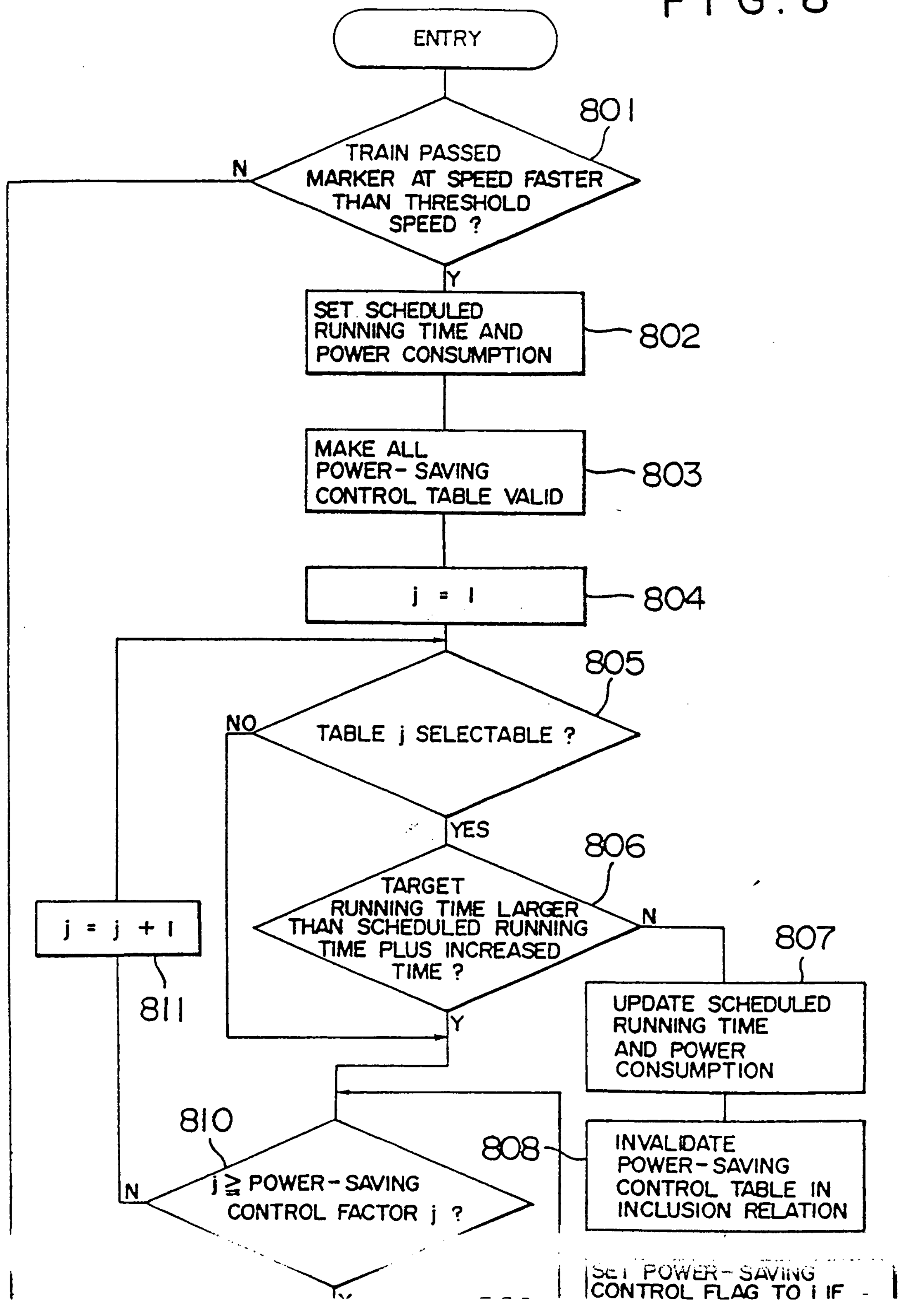

A
CALCULATE UPPER TARGET SPEED v_{TV}
711
MAKE LOWER TARGET SPEED v_{TL} BELOW v_{TV}
712
CALCULATE BRAKE COMMAND
713
714
BRAKE COMMAND ISSUED ?
NO
YES
716
CALCULATE TRACTION COMMAND
715
CANCEL TRACTION COMMAND
OUTPUT TRACTION OR BRAKE COMMAND TO DRIVE CONTROLLER
717
END

FIG. 8


ENTRY
801
TRAIN PASSED MARKER AT SPEED FASTER THAN THRESHOLD SPEED ?
N
Y
SET SCHEDULED RUNNING TIME AND POWER CONSUMPTION
802
MAKE ALL POWER-SAVING CONTROL TABLE VALID
803
j = 1
804
805
TABLE j SELECTABLE ?
NO
YES
806
TARGET RUNNING TIME LARGER THAN SCHEDULED RUNNING TIME PLUS INCREASED TIME ?
N
Y
807
UPDATE SCHEDULED RUNNING TIME AND POWER CONSUMPTION
j = j + 1
811
808
INVALIDATE POWER-SAVING CONTROL TABLE IN INCLUSION RELATION
810
j ≧ POWER-SAVING CONTROL FACTOR j ?
N
SET POWER-SAVING CONTROL FLAG TO 1 IF

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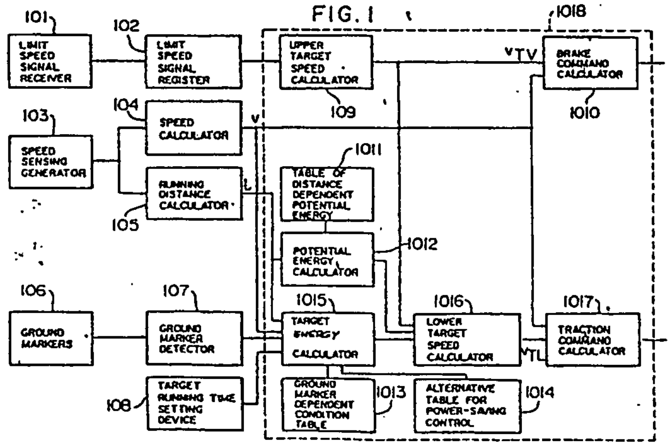
(54) **Method for automatically controlling a vehicle.**

(57) This invention relates to a method of automatic vehicle operation which fulfills multi-dimensional performance indices by presetting the weight for power consumption, the weight for the riding confort, and the like. The modifying running time relative to the standard running time to be spent between two stations, the allowable power consumption relative to the standard power consumption to be spent for the standard running between two stations, and the degree of improvement of riding confort for the standard running between two stations are set prior to the departure from a station so as to determine control parameters to be used for divided regions of distance between two stations, and the speed of the vehicle between two stations is controlled using the selected control parameters.

FIG. 1



EP 0 257 662 A3

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EUROPEAN SEARCH REPORT

Application Number

EP 87 11 4703

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.3)
A	US-A-4 181 943 (MERCER et al.) * column 2, line 56 - column 3, line 12; column 4, lines 31-54; figures 1, 2 *	1,4,6	B 60 L 15/20 B 60 L 3/00
A	DE-A-3 026 652 (SIEMENS AG) * page 8, line 17 - pge 11, line 36; page 14, line 24 - page 16, line 34; figures 1, 2, 6 *	1,4-6	
A	US-A-3 604 905 (RIONDEL) * column 2, lines 3-31; figures 1, 3 *	1	
A	US-A-4 179 739 (VIRNOT) * column 2, lines 24-59 *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.3)
			B 60 L 15/00 B 60 L 3/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	01-02-1988	WEIHS J.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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